HISTORY OF GEOLOGICAL AND PALAEONTOLOGICAL STUDIES ON THE PERMIAN GLACIALLY DERIVED SEQUENCES OF THE BACCHUS MARSH DISTRICT, VICTORIA, AUSTRALIA

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The Permian sediments of the Bacchus Marsh District were first recorded by Alfred R. C. Selwyn in 1859 with a possible glacial origin being suggested for the sediments by Selwyn in 1861. The search for reliable proof of the association of the sediments with glacial conditions was rewarded by the 1890s with numerous discoveries of striated boulders and glacial pavements. Contributions by such geologists as E. J. Dunn, C. C. Brittlebank, G. Officer, L. Balfour, E. G. Hogg, G. Sweet and T. W. E. David are particularly noteworthy. Impetus for these late 19th Century contributions appears to have been generated, at least in part, by the field excursion activities of the Field Naturalists Club of Victoria and the stimulus provided by the Research Committee on glacial action in Australia established by the Australasian Association for the Advancement of Science.

The report of the discovery of species of the plant *Gangamopteris* from the Bacchus Marsh Sandstones was announced by Frederick McCoy in 1861. Assignment of the genus to the Early Mesozoic by McCoy initiated a debate for over forty years over the age of the sandstones. A. R. C. Selwyn and R. Daintree writing in the 1860s appeared to favour a Late Palaeozoic age but the Early Mesozoic age estimate achieved prominence in Victoria until the close of the 19th Century. Palaeontological discoveries during the 20th Century have increasingly added to the interpretation that all the Victorian Permian deposits are Early Permian in age.

THE PERMIAN glacially derived sequences of the Bacchus Marsh District, Victoria, Australia, have long attracted global interest because of the close association between their glacial (including fluvio-glacial and glacio-marine) origin and the occurrence of elements of the *Glossopteris* flora. A geological excursion to the Bacchus Marsh District was organised as part of the Strzelecki International Symposium (held at Rusden Campus of Deakin University and the Royal Society of Victoria's Hall, 30 November–3 December 1997) and an excursion guide was prepared (Archbold et al. 1997).

During the preparation of the excursion guide it became clear to the writers that many significant 19th Century works were often overlooked by more recent authors. Hence this review has been written in order to summarise these older works and to provide a bibliography of works describing the Permian geology and palaeontology of the Bacchus Marsh District, many of which are relatively obscure and difficult to locate. Dunn & Mahony (1910) provide comprehensive biographies and bibliographies of the founders of the Geological Survey of Victoria and this work has been an invaluable source for seldom quoted references.

INTRODUCTION

The Permian sedimentary successions of the Bacchus Marsh area, central Victoria and their glacigene origin have been the subject of considerable interest since the first report of sediments 'very suggestive of the results likely to be produced by marine glacial transport; and the mixture of coarse and fine material, both water-worn and angular, much of which has clearly been derived from remote localities ...' by Alfred Richard Cecil Selwyn (1824–1902) then Director of the Geological Society of Victoria (also referred to as the Government Geologist of the Colony of Victoria) (Selwyn 1861a: 184).

In an earlier article, Selwyn (1859) had referred to the 'coal bearing rocks' of Victoria and had noted that 'patches of these rocks also occur near Bacchus Marsh' and that these represented the 'best freestone for building which has yet been obtained in the colony' (Selwyn 1859: lxiii). He noted that they had yielded no fauna but rather a flora 'of an oolitic type' as determined by Frederick McCoy. In a somewhat prophetic comment Selwyn also noted that these rocks demonstrated 'more resemblance to the Carboniferous than the oolitic rocks of Europe'. Selwyn (1860: 4) on the 14 May 1859 had also discovered in the Inman River Valley, South Australia, 'a smooth striated and grooved rock surface, presenting every indication of glacial action' that would much later also prove to be Early Permian in age.

Bacchus Marsh is located some 50 km west of Melbourne (Fig. 1) and outcrops of Permian sediments are scattered throughout the area in patches invariably controlled by numerous faults. Most faults exhibit general east–west trends and evidence of movement extends back to the Permian

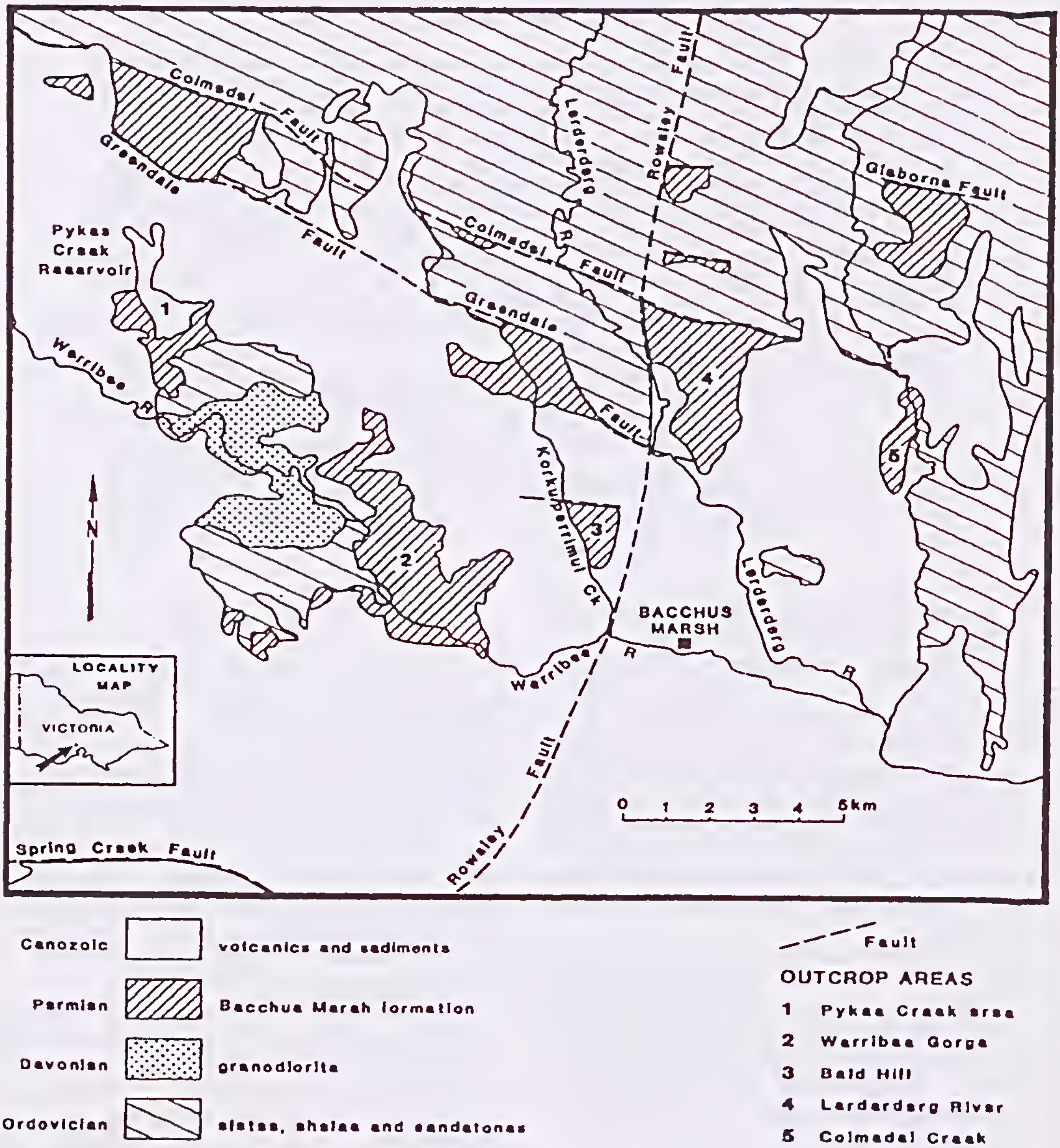


Fig. 1. Distribution of Permian sediments in the Bacchus Marsh District. Reprinted from *Engineering geology of Melbourne—Proceedings of the seminar, Melbourne, Victoria, Australia, 16 September 1992*, W. A. Peck, J. L. Neilson, R. J. Olds & K. D. Seddon, eds, 1992, 418 pp., Hfl. 190/US$95.00. A. A. Balkema, PO Box 1675, Rotterdam, Netherlands. Please order from: D. A. Book (Aust.) Pty, PO Box 163, Mitcham, Victoria 3132, Australia [*tel.:* (03) 9210 7777; *telefax:* (03) 9210 7788; *e-mail:* service@dadirect.com.au.

(O'Brien 1996). Movement on the east–west trending faults antedates movement on the north–south Rowsley fault which was active during the Tertiary and Quaternary (Singleton 1967, 1968; O'Brien 1996). The area still experiences minor seismicity.

Geological setting of the Permian sediments

The Permian sediments of the Bacchus Marsh Area rest unconformably on Ordovician and Devonian basement rocks. The Ordovician rocks consist of tightly folded and faulted mudstones and fine sandstones (the mudstones invariably with slaty cleavage) with minor coarse sandstones and fine pebble conglomerate beds. The slates and mudstones contain impressive sequences of graptolite assemblages (Cas & VandenBerg 1988). These Ordovician sequences form part of the rock sequences of the Lachlan Foldbelt of southeastern Australia and are of a turbiditic origin.

Devonian granitic rocks and associated porphyritic felsic dykes intruded the Ordovician sequences and resulted in contact metamorphism producing tough, dark hornfels and minor quartzites. Quartz veins cross cut the Ordovician sequences and are common. All these rocks, in addition to metamorphosed Cambrian volcanics, Late Silurian red bed facies sandstones and Siluro-Devonian marine mudstones and sandstones (all from outside the Bacchus Marsh Area) form the minimum rock suites that contributed to the detritus of the Permian glacigene sequence.

Low in the Permian sequence, erratic pebbles and boulders are dominated by local sources from the Ordovician sequences but the proportion of exotic erratics increases higher in the sequence with numerous granitic types, rhyolite, quartzite, conglomerate, schist and gneiss invariably of unknown source (Singleton 1967). Selwyn (1861b: 155) had listed granite, greenstone, various porphyries, hard slate, gritty sandstone, grey quartz rock and quartz among the pebbles and boulders.

As the knowledge of modern sedimentary depositional processes has advanced so to has the complexity of the interpretation of ancient sedimentary sequences. Whereas the geologists of last century referred to the conglomerates and sandstones of the Bacchus Marsh District and searched for glacial evidence such as striated boulders and pavements, modern sedimentary studies recognise a complex of sedimentary environments. O'Brien (1996) recognised 5 major categories of diamictite representing subglacial lodgement tillites, supraglacial tillites, possible mudflow deposits or transitional glacial marine facies and subglacial tillites lacking any evidence of water sorting or slump deformation. Ice-rafted facies, deltaic and subaqueous outwash fans, fluvial facies and, at least, 2 intervals of deposition into standing bodies of marine water have been recognised (O'Brien 1996).

Overlying the Permian sequences in the Bacchus Marsh Area are patches of Triassic non-marine sequences (minor), Paleogene and Early Neogene basaltic volcanics, Paleogene and Neogene non-marine sedimentary sequences including coal (lignite), Late Neogene-Quaternary basaltic volcanics and Recent alluvial and colluvial deposits (Summers 1923; Singleton 1968; Roberts 1984).

HISTORY OF INVESTIGATIONS

Despite the early suggestion by Selwyn (1861a, 1861b) that the 'conglomerate beds' were suggestive of 'marine glacial transport' he noted that 'grooved or ice-scratched pebbles or rock fragments' had 'not yet been observed' (Selwyn 1867). Richard Daintree (1831–1878) when writing of the conglomerates of the Werribee Gorge, (Daintree 1863a, 1863b, 1897) did not mention striated boulders but later (1866: 11) he noted that from the 'mud pebble-beds, on the Lerderderg River, immediately below where that river leaves the ranges' he had 'found a few pebbles grooved in the manner I have read of as caused by glacial action'. Daintree (1863b: 20) had compared the 'conglomerates and freestones of Werribee Gorge' with 'possibly old red sandstone' but decided that they had 'better be treated under the head of Upper Paleozoic' ... 'until more fossils are collected from the series to determine their European parallel'. [*Bibliographical note:* Daintree (1863a) appears to be a very rare publication. According to Selwyn (1863: 4, 12) it was published on either 21 or 28 May 1863. Dunn & Mahony (1910: 20) give the date as 21 May and that is the date on the publication itself. Daintree (1863b) is also rare and is undated. I am assuming it was issued as a separate pamphlet in 1863.]

Daintree and Charles Smith Wilkinson (1843–1891) prepared the elegant, detailed quarter-sheet of the Bacchus Marsh District at a scale of 2 miles to the inch, which was published in 1868. Detailed cross-sections and notes followed a year later (Daintree & Wilkinson 1869). No reference is made in the notes to a possible glacial origin. Several of the notes are taken directly from Selwyn (1867). The published map and sections testify to the quality of the staff of the Geological Survey of

Victoria under the direction of A. R. C. Selwyn (Darragh 1977). Despite these early comments, mapping and sections, and the debate concerning the age of the rocks and their fossils of the plant *Gangamopteris* (see discussion below), surprisingly little in the way of additional detailed observations on the rock sequences seems to have occurred until the 1890s. Reginald A. F. Murray (1884a: 51) referred in passing to the 'thick-bedded sandstones, shales and mudstone conglomerates' flanking the ranges of the Lerderderg and of the Werribee Gorge'. Additional data were provided in Murray's second report (1884b: 80) wherein he noted that sandstones were prominent in the upper beds whereas 'the lower beds of the series ... in many places consist of conglomerate'. He repeated Selwyn's comment that 'grooved or ice-scratched pebbles have not been observed'. Murray also noted that 'sub-angular pieces of granite of a different character to any occurring in situ in the district' had been found and that he had 'heard the late Sir R. Daintree state that some of these fragments resembled no granite he was acquainted with occurring as a rock-mass nearer than Queensland'. E. J. Dunn (1887) discovered striated boulders and pebbles in the 'conglomerate' near Beechworth, northeastern Victoria, and also observed 'flat surfaces, and the peculiar fractures of the pebbles, so characteristic of conglomerates that have been formed through glacial action'. He compared the Victorian 'conglomerate' with the Dwyka conglomerate of South Africa, which he had personally studied, and elaborated further on his observations and conclusions in a later paper (Dunn 1890a).

Dunn (1889) visited the Bacchus Marsh Area and remarked on the diversity of the lithological constituents of the conglomerate. He noted that 'the forms of the included materials and the striatures and grooves on their surfaces prove that this conglomerate is of glacial origin' (Dunn 1889: 81). Murray (1890: 19) appears to have been unaware of Dunn's observations for he states that 'no ice-scratched fragments have yet been observed' in the rocks occurring at Bacchus Marsh. Dunn (1890b) also commented on the nature of the sandstones (freestones) of the Bacchus Marsh District and the need for good building stone in Melbourne. The Bacchus Marsh Sandstones had previously been used for public buildings in Melbourne including the (old) Treasury building, the Parliamentary Library and the (old) Custom House (Selwyn 1867), the stone coming from quarries opened in the late 1850s. In the Royal Society of Victoria's 'Report on The Resources of the Colony of Victoria' dated 9 April 1860, it is noted that 'the Bacchus Marsh Stone is being used in the erection of the new Treasury, and Custom House' and that 'the stone belongs to the coal formation' (Mueller & Irving 1860: 14). Also noted is that 'beautiful fossil vegetable impressions abound in the above quarries'—presumably referring to specimens of *Gangamopteris*. Subsequently sandstone from near Greendale was used for numerous public building purposes in the village of Greendale (Baragwanath 1917a) and sandstone from Ballan was used for the private Hunterston Homestead (Baragwanath 1917b). The Court House at Bacchus Marsh also is built of these sandstones (Summers 1923). David (1887) provided a contemporary review of early observations on the Bacchus Marsh sequences but had not yet visited the Victorian localities. This he would achieve in December 1894 (David 1896a). David (1890: 461, 463) had also previously indicated that the 'Bacchus Marsh Sandstone, containing *Gangamopteris* may be the equivalent of part of the New South Wales, Permo-Carboniferous system' and that a plant 'seemingly allied to *Gangamopteris*' had been found in 'a low horizon of the lower marine series'.

The 1890s witnessed a flurry of investigations on the Permian sequences of the Bacchus Marsh District by such geologists as Graham Officer, Evelyn G. Hogg, Lewis Balfour, George Sweet, Tannatt William Edgeworth David and Charles Clifton Brittlebank (the last being a resident to the north of the Werribee Gorge in the residence known as 'Dunbar'). At least two activities by learned societies appear to have stimulated portion of this renewed activity. The first was the frequent excursions by the Field Naturalists' Club of Victoria to the Werribee Gorge during the 1890s (see Best & Sweet 1891; Barnard 1894, 1908; Hall 1895) with leaders such as Sweet, Brittlebank and G. B. Pritchard. The second was the impetus for investigations provided by the Research Committee appointed to collect evidence as to glacial action in Australasia by the Australasian Association for the Advancement of Science.

Striated pebbles and boulders (Ferguson 1891; Officer & Balfour 1893, 1894; Sweet & Brittlebank 1893; David 1896a, 1896b) were cited as the strongest evidence for a glacial origin in addition to the occurrences of striated pavements or *roche moutonnées* (Sweet & Brittlebank 1893; Officer & Balfour 1893, 1894; Officer et al. 1896; Brittlebank et al. 1898; Brittlebank 1901). Increasing attention was paid to subdivisions of the Permian sequence and stratigraphical columns (David 1896b; Officer & Balfour 1894). Some degree of misunderstanding as to who were the prior workers in the area appears to have existed between Sweet and Brittlebank on the one hand and Officer and Balfour on the other (e.g. see Officer & Balfour 1896; Brittlebank et al. 1898). Despite these difficulties the quality of the observations of these workers in the 1890s was substantial. Brittlebank was a careful map producer and drawer of sections. His detailed map of 1893, based in part on Daintree and Wilkinson's map, extends the area of the latter map to the north (see pl. 12 of Sweet & Brittlebank 1893). Brittlebank appears to have drafted this map and also that of 1898 (in Brittlebank et al. 1898) although other geologists such as Sweet or David were involved with field work in his company. He also took part in the measurement of sections (e.g. that in pl. 12 of David's 1896b work). Probably his finest detailed work was the geological sketch plan and section of the Werribee Gorge published in 1899. Brittlebank (1896) also provided detailed observations on the Tertiary units overlying the glacial sequences, the relationships of the glacials to the underlying rocks (Brittlebank 1901) and the rate of erosion of the valleys of the Werribee and Lerderderg rivers (Brittlebank 1900).

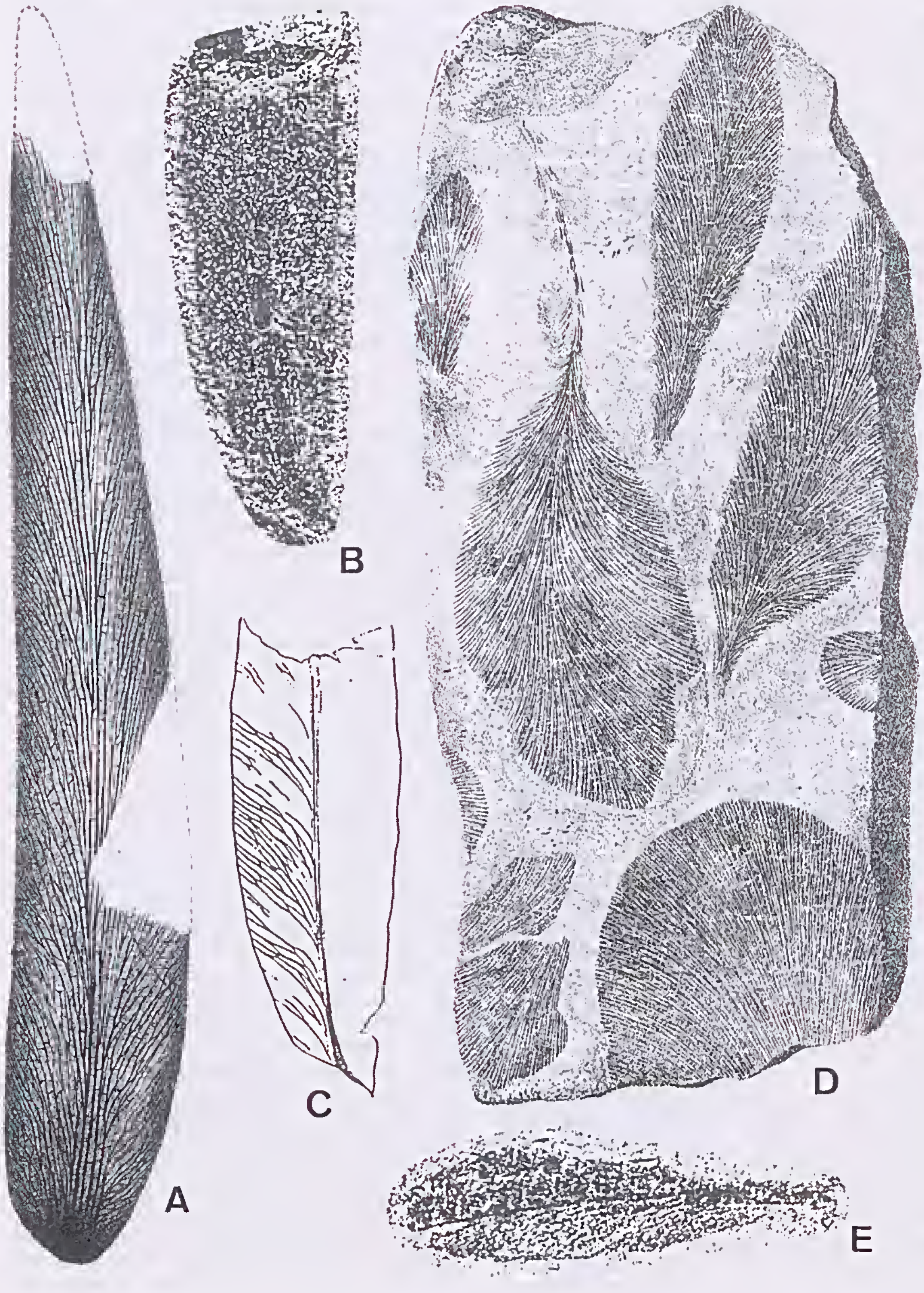
Several of these early workers gave informal names to the glacigene sediments such as Bacchus Marsh Glacial Conglomerate (David 1896), Bacchus Marsh Sandstones (Officer & Balfour 1894; Pritchard 1910), Permo-Carboniferous Glacial Beds (Officer & Hogg 1897). All Permian sediments in the Bacchus Marsh area were formally named as the Bacchus Marsh Formation by Roberts (1984) who also named one conglomerate bed at Korkuperrimul Creek the Morton Conglomerate Member.

Numerous published accounts during the 20th Century have added to the regional geology (e.g. Pritchard 1914; Fenner 1918; Ferguson 1920; Howchin 1920; Summers 1923, 1935; David 1932; Jacobson & Scott 1937; Mahony 1937; Kenley 1952; Bowen 1958; Bowen & Thomas 1976; and Crowell & Frakes 1971a, 1971b). Specific site descriptions have been provided by Brittlebank (1899), Hall (1909), Robbins (1973a, 1973b), Davis & Mallett (1981), Roberts (1984), Quick (1988) and O'Brien (1989). The surface texture of sand-grains was described by Hamilton & Krinsley (1967). A series of reviews have been published during the last 30 years approaching the interpretation of the Permian sequences from different aspects (Spencer-Jones 1969; Singleton 1968; Bowen & Thomas 1976, 1988; VandenBerg 1988; O'Brien 1981, 1996; Archbold 1992). O'Brien (1996) has provided the most comprehensive and detailed descriptions of lithologies, facies and interpretations of the Permian sequences in the light of recent work on modern and Pleistocene glacial sequences. Unfortunately, O'Brien's 1996 work is a rare, local publication of limited circulation.

AGE OF THE PERMIAN SEQUENCES

The Permian glacial sediments of Bacchus Marsh have yielded a range of palaeontological materials including leaves, palynological samples and marine fossils the latter indicating two brief marine incursions into the region.

The earliest work centred on the discovery of fossil leaves of which Clarke (1861a: 92) noted 'what I saw in the museum of so-called *Glossopteris Browniana*, from Darley and Bacchus Marsh, did not appear to me to be certain evidence of the species'. McCoy (1861a: 107) confirmed that he had 'not yet seen perfectly decisive specimens ... of the *Glossopteris*' but that he had an 'abundance of fronds of a new genus' that he had previously figured from New South Wales as *Cyclopteris*. Selwyn (1861a: 182, 1861b: 154), also referred to *Cyclopteris* from Bacchus Marsh, following the identification of the genus by McCoy. McCoy, in a footnote, on the same page of the above publication (McCoy 1861a) named the new genus *Gangamopteris*. McCoy maintained that the fossil leaves were Mesozoic and hence began a long debate on the age of the sandstones (Clarke 1861b, 1878; McCoy 1861b, 1867, 1875; Selwyn 1861a, 1867; Feistmantel 1878; Murray 1884a, 1884b and others—see Rigby & Chandra 1990 for a modern review of the controversy). McCoy (1875) described and illustrated the fossil leaves and described three species, *Gangamopteris angustifolia*, *G. spatulata* and *G. obliqua*. The first species was misspelt as *augustifolius* in McCoy (1867) and misquoted as *Gangemopteris* (*sic*) *longifolius* in Selwyn (1867), Daintree (1866) and Daintree & Wilkinson (1869). The misquotation of the name was also repeated in Ulrich (1874: 58, 1875: 76, 78) in his catalogues of specimens in the Industrial and Technological Museum (Melbourne). David (1896a: 62) in a series of quotations from Daintree (1866) corrected the spelling of *Gangamopteris* but retained the incorrect species name. It is noteworthy that one of McCoy's two plates (pl. 13, figs 1, 1a, 2, 2a) which illustrated his account of the two *Gangamopteris* species *angustifolia* and *spatulata* had been prepared some 15 years prior to publication by the German artist–naturalist, Ludwig Becker (1808–1861). Becker worked for McCoy from July 1858 until January 1859 producing drawings and lithographic plates (Darragh 1997). In view of the fact that at least some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specimens of the *Gangamopteris* were available no later than early 1859, it is perhaps surprising that no mention was made of them in McCoy's (1861c) essay. The reports of Selwyn, Daintree & Daintree and Wilkinson generally favoured an Upper Palaeozoic age for the sedimentary succession but a transitional 'Carbonaceous' period or Lower Mesozoic age progressively was used by the Geological Survey of Victoria into the 1890s. Murray exchanged data with Charles Wilkinson, a person with, 'long practical experience in both colonies' and concluded that an early Mesozoic age was preferable for the *Gangamopteris* sandstones—a view maintained in both editions of his Geology and Physical Geography of Victoria (Murray 1887, 1895). Dunn (1892: 3), however, considered that 'the balance of evidence favours the view that these rocks are of Palaeozoic age'. Clarke (1861a, 1861b, 1878) argued strongly for a Carboniferous age for the *Glossopteris* coal measures of New South Wales contrary to the views of McCoy and others who '... have so long disputed facts attested by geologists in New South Wales who are familiar with that Colony and with Victoria also, but who are ignored by the closet—geologists of the latter' (Clarke 1878: 7). It is noteworthy that the debate over the age of the sequences 'saved for the geologists of India the credit for establishing the non-European character of Late Palaeozoic successions in the southern lands' (Vallance 1975: 30). [*Bibliographical note:* The essays published by Selwyn (1861a) and McCoy (1861e) were also published in German (Selwyn 1861c; McCoy 1861d) and in French (not seen by the present author) in editions for the London International Exhibition of 1862.]

Kovacs-Endrody (1977) and Rigby & Chandra (1990) repeated McCoy's (1875) illustrations or refigured specimens. Additional plant remains were mentioned or described by McCoy (1892, 1894; in an appendix in Officer & Balfour 1894, 1895, 1898) and Pritchard (1910) but these are essentially unidentifiable in modern terms. Chapman (1906) described a specimen he referred *Gangamopteris* which has subsequently been referred to *Glossopteris* (see Rigby & Chandra 1990). The most recent revision of the macro plant fossils from the Permian of Bacchus Marsh is that of Rigby & Chandra (1990) who documented the mixed *Gangamopteris–Glossopteris* nature of the flora and favoured an early Permian age. Several figures from McCoy (1875) and Rigby & Chandra (1990) are repeated herein (Fig. 2).

Sporomorphs from a tillitic rock in Coimadai Creek, Bacchus Marsh, have been described by Virkki (1939, 1946), Pant (1949, 1955) and Pant & Mehra (1963) and reviewed by Douglas (1969). All these reports indicate an Early Permian age for their localities. Truswell (in O'Brien 1996: 2) reported on a microflora from samples from the Lerderderg River and assigned it to the 'Stage 2 Microflora Zone' which is most likely Asselian and Early Sakmarian (Tastubian) in age (Archbold 1982, 1995). Modern work is required in order to fully assess any range in ages for the various spore yielding localities.

Two marine incursions are recognised in the Permian sequences of the Bacchus Marsh area based on the discovery of marine fossils (Garratt 1969; Thomas 1969) at localities adjacent to Korkuperrimul and Coimadai Creeks. One of the incursions, on the basis of the discovery of *Notoconularia inornata* (Dana, 1849), appears to be no older than Artinskian (Thomas 1969). This marine incursion is represented by a conglomerate bed (the Morton Conglomerate Member as defined by Roberts 1984) that rests unconformably on the *Gangamopteris–Glossopteris* bearing sandstones.

The second marine incursion is known from marine fossils discovered in a conglomerate lens on the western side of Coimadai (or Pyrete) Creek (now submerged beneath the waters of Lake Merrimu). Fragmentary *Paraconularia* sp. (Garratt 1969; Thomas 1969) and the brachiopod *Trigonotreta victoriae* Archbold (1991) are characteristic of the faunal assemblage and a Late Asselian–Tastubian age is preferred for this marine incursion (Archbold 1991). Illustrations of marine fossils (Fig. 3) are after Thomas (1969) and Archbold (1991).

No palaeontological data yet exists indicating ages for the Permian sequences of Bacchus Marsh being younger than Early Permian.

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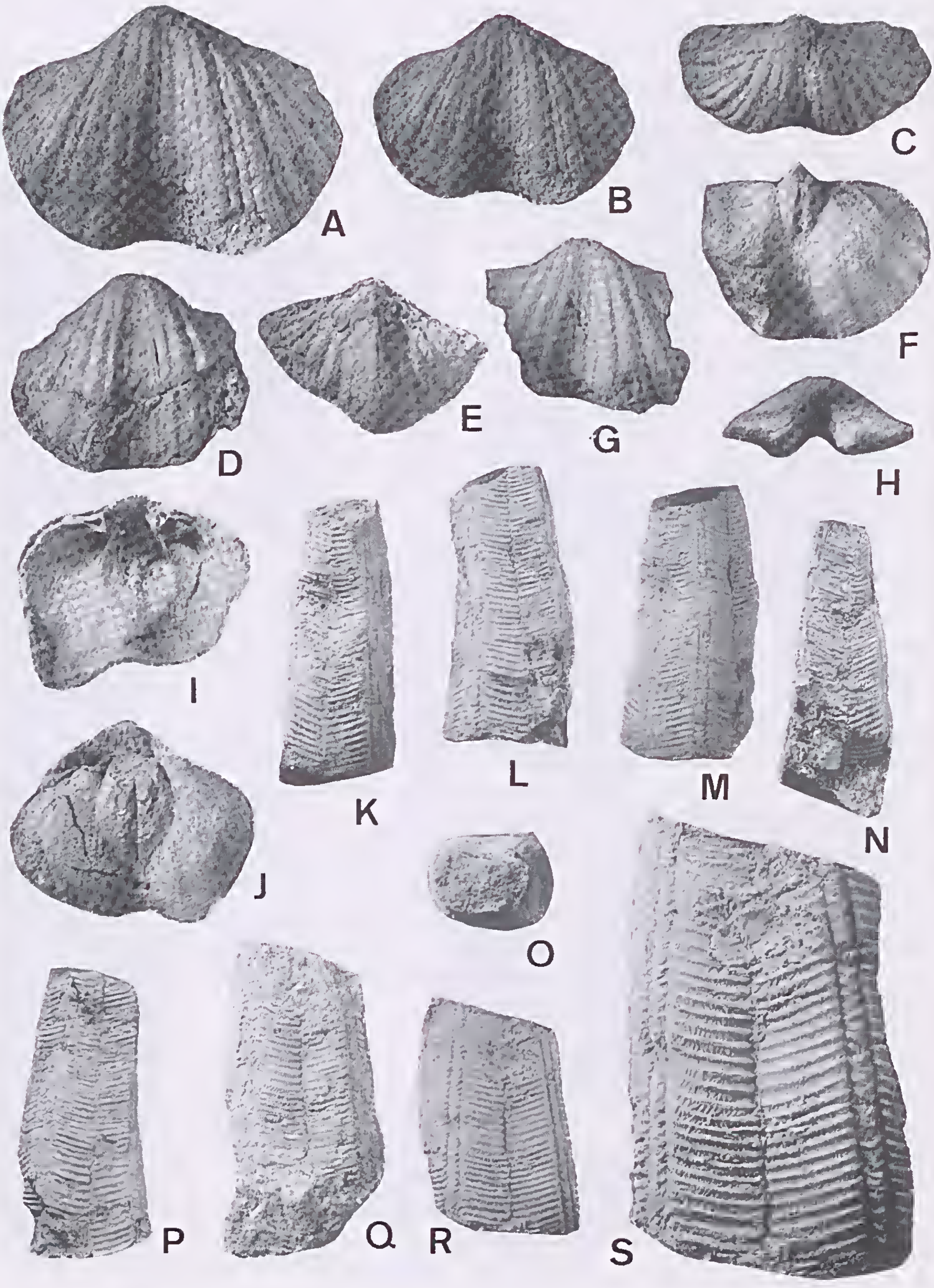
Fig. 2. Permian plants from Bacchus Marsh, Victoria. A, *Gangamopteris angustifolia* McCoy (after McCoy 1875: pl. 12, fig. 1). B, C, E, *Glossopteris douglasii* Rigby & Chandra (after Rigby & Chandra 1990: figs 2D, 2E, 3). D, *Gangamopteris spatulata* McCoy (after McCoy 1875: pl. 13, fig. 1).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Roehstein for word-processing the manuscript. Fig. 1 is reproduced courtesy of A. A. Balkema, Publishers, The Netherlands.

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Fig. 3. Permian marine invertebrates from Bacchus Marsh, Victoria. A–J, *Trigonotreta victoriae* Archbold (after Archbold 1991: figs 2A–D, F, H–J, O, S). K–S, *Notoconularia inornata* Dana (after Thomas 1969: pl. 149, figs 1a–1f, 4a–4c).

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ADDENDUM

Correlation of the *Gangamopteris* flora of the Bacchus Marsh Sandstones with the New South Wales rock sequences was a question of considerable discussion during the 1880s. Feistmantel (1878: 163) had previously suggested a possible correlation of the Bacchus Marsh Sandstones 'partly on the horizon of the Newcastle beds'. Murray (1887: 85) quoting C. S. Wilkinson's opinions, correlated the Bacchus Marsh Sandstones with the Hawkesbury Sandstones of New South Wales (Triassic cf. David 1888, 1889). stratigraphically above the Newcastle coal measures. However by 1887, *Gangamopteris* had only been clearly recognised from the Newcastle beds not from the sequences above or below (Feistmantel 1878: 161; Oldham 1886: 45). David (1890: 461) considered the possibility that the Bacchus Marsh Sandstones could be contemporaneous with part of the Permo-Carboniferous system of New South Wales. The term Permo-Carboniferous was used by David (1889: 278) to include the Newcastle coal measures, whereas previously (1887: 190, 1888: 83) he had referred them to the Permian, following the classificaton of C. S. Wilkinson. David (1890: 463) appears to have been the first to record a probable *Gangamopteris* specimen from much lower than the Newcastle series in the lower marine series below the Greta coal measures, thereby paving the way for an Early Permian age for the Bacchus Marsh Sandstones.